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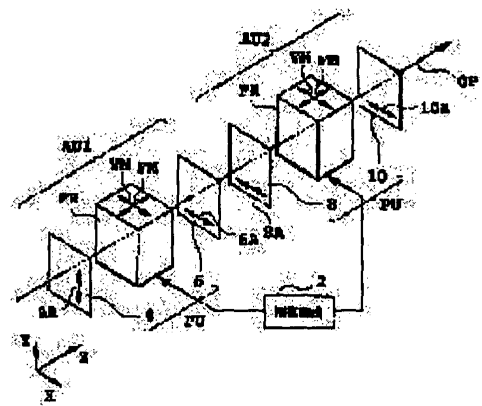
(54) OPTICAL ATTENUATOR, SYSTEM PROVIDED WITH THE ATTENUATOR, OPTICAL AMPLIFIER AND TERMINAL STATION DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To make an optical attenuator provided with two Faraday rotators flat in wavelength characteristics of attenuation.
SOLUTION: This optical attenuator consists of two attenuator units AU1 and AU2 which are cascaded and a control circuit 2 which is connected thereto, each attenuator consists of a Faraday rotator FR whose angle of Faraday rotation depends upon wavelength and a polarization unit PU for causing attenuation determined by Faraday rotation angle, and wavelength characteristics of attenuation of one attenuator unit are canceled by those of the other attenuator.



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CLAIMS

[Claim(s)]
[Claim 1] The optical attenuator characterized by providing the following. The 1st and the 2nd attenuator unit by which the cascade connection was carried out on the optical path. this -- the Faraday-rotation child for producing the Faraday-rotation angle which it has the control circuit connected to the 1st and 2nd attenuator units, and each of the above 1st and the 2nd attenuator unit is arranged on the above-mentioned optical path, and is given as a function of wavelength The above-mentioned control circuit is a means to control each above-mentioned Faraday-rotation angle so that the wavelength property of the attenuation in the attenuator unit of the above 1st is substantially offset by the wavelength property of the attenuation in the attenuator unit of the above 2nd, including the polarization means for producing the attenuation determined according to the above-mentioned Faraday-rotation angle about the above-mentioned optical path.
[Claim 2] It is an optical attenuator according to claim 1. the polarization means of the attenuator unit of the above 1st It consists of the 1st and 2nd polarizers formed on the above-mentioned optical path so that the Faraday-rotation child of the attenuator unit of the above 1st may be inserted. the polarization means of the attenuator unit of the above 2nd It is the optical attenuator which consists of the 3rd and 4th polarizers formed on the above-mentioned optical path so that the Faraday-rotation child of the attenuator unit of the above 2nd may be inserted, and has the shaft which determines the plane of polarization of the polarization which each of the above 1st or the 4th polarizer passes.
[Claim 3] It is an optical attenuator containing the electromagnet for being an optical attenuator according to claim 2, and each above-mentioned Faraday-rotation child impressing the magneto optics crystal prepared so that the above-mentioned optical path may pass, and the adjustable magnetic field according to the given current to the above-mentioned magneto optics crystal.
[Claim 4] It is an optical attenuator according to claim 3, the attenuator unit of the above 1st is prepared so that attenuation by the attenuator unit of the above 1st may increase according to the current given the account of a top increasing, and the attenuator unit of the above 2nd is an optical attenuator prepared so that attenuation by the attenuator unit of the above 2nd may decrease according to the given current increasing the account of a top.
[Claim 5] Are an optical attenuator according to claim 3, and the shaft of the above 1st and the 2nd polarizer lies at right angles mutually. The shaft of the above 3rd and the 4th polarizer is mutually parallel, and each adjustable magnetic field impressed with each above-mentioned electromagnet is substantially perpendicular to the above-mentioned optical path. each above-mentioned Faraday-rotation child The optical attenuator which contains further the permanent magnet for impressing a fixed field system to each above-mentioned magneto optics crystal so that each above-mentioned Faraday-rotation angle may become 90 degrees substantially, when the current given the account of a top is zero.
[Claim 6] Are an optical attenuator according to claim 3, and the shaft of the above 1st and the 2nd polarizer lies at right angles mutually. The magnetic field which the shaft of the above 3rd and the 4th polarizer lies at right angles mutually, and is impressed with the electromagnet of the attenuator unit of the above 1st is substantially perpendicular to the above-mentioned optical path. The Faraday-rotation child of the attenuator unit of the above 1st The permanent magnet for impressing a fixed field system to the above-mentioned magneto optics crystal so that the above-mentioned Faraday-rotation angle may become 90 degrees substantially, when the current given the account of a top is zero is included further. The magnetic field impressed with the electromagnet of the attenuator unit of the above 2nd is an parallel optical attenuator substantially to the above-mentioned optical path.
[Claim 7] It is an optical attenuator according to claim 1. the polarization means of the attenuator unit of the above 1st The 1st and 2nd birefringence crystals prepared so that the Faraday-rotation child of the attenuator unit of the above 1st may be inserted are included. the polarization means of the attenuator unit of the above 2nd The 3rd and 4th birefringence crystals prepared so that the Faraday-rotation child of the attenuator unit of the above 2nd may be

inserted are included. The 1st optical fiber for the above-mentioned optical path being offered by the ordinary ray and extraordinary ray by which each of the above 1st or the 4th birefringence crystal is defined, and supplying light on the above-mentioned optical path, The optical attenuator further equipped with the 2nd optical fiber optically combined with the 1st optical fiber of the above at the joint efficiency according to each above-mentioned Faraday-rotation angle.

[Claim 8] It is the optical attenuator which has the main shaft as which it is an optical attenuator according to claim 7, and each of the above 1st or the 4th birefringence crystal determines the above-mentioned ordinary ray and the above-mentioned extraordinary ray.

[Claim 9] It is an optical attenuator containing the electromagnet for being an optical attenuator according to claim 8, and each above-mentioned Faraday-rotation child impressing the magneto optics crystal prepared so that the above-mentioned optical path may pass, and the adjustable magnetic field according to the given current to the above-mentioned magneto optics crystal.

[Claim 10] It is an optical attenuator according to claim 9, the attenuator unit of the above 1st is prepared so that attenuation by the attenuator unit of the above 1st may increase according to the current given the account of a top increasing, and the attenuator unit of the above 2nd is an optical attenuator prepared so that attenuation by the attenuator unit of the above 2nd may decrease according to the given current increasing the account of a top.

[Claim 11] Are an optical attenuator according to claim 9, and the main shaft of the above 1st and the 2nd birefringence crystal lies at right angles mutually. The main shaft of the above 3rd and the 4th birefringence crystal is mutually parallel, and each adjustable magnetic field impressed with each above-mentioned electromagnet is substantially perpendicular to the above-mentioned optical path. each above-mentioned Faraday-rotation child The optical attenuator which contains further the permanent magnet for impressing a fixed field system to each above-mentioned magneto optics crystal so that each above-mentioned Faraday-rotation angle may become 90 degrees substantially, when the current given the account of a top is zero.

[Claim 12] Are an optical attenuator according to claim 9, and the main shaft of the above 1st and the 2nd birefringence crystal lies at right angles mutually. The magnetic field which the main shaft of the above 3rd and the 4th birefringence crystal lies at right angles mutually, and is impressed with the electromagnet of the attenuator unit of the above 1st is substantially perpendicular to the above-mentioned optical path. The Faraday-rotation child of the attenuator unit of the above 1st The permanent magnet for impressing a fixed field system to the above-mentioned magneto optics crystal so that the above-mentioned Faraday-rotation angle may become 90 degrees substantially, when the current given the account of a top is zero is included further. The magnetic field impressed with the electromagnet of the attenuator unit of the above 2nd is an parallel optical attenuator substantially to the above-mentioned optical path.

[Claim 13] It is the optical attenuator which consists of a wedge board which has the wedge angle as which each of the above 3rd and the 4th birefringence crystal is defined on the 2nd flat surface by being an optical attenuator according to claim 7, and each of the above 1st and the 2nd birefringence crystal consisting of a wedge board which has the wedge angle defined on the 1st flat surface.

[Claim 14] It is an optical attenuator according to claim 13, and the above 1st and the 2nd flat surface are an optical attenuator which is not parallel mutually.

[Claim 15] It is the optical attenuator which is an optical attenuator according to claim 13, and was further equipped with the 3rd optical fiber for the above 1st and the 2nd flat surface being mutually parallel, and connecting the above 1st and the 2nd attenuator unit optically.

[Claim 16] The optical attenuator according to claim 1 characterized by providing the following. Each above-mentioned Faraday-rotation child is a magneto optics crystal prepared so that the above-mentioned optical path may pass. A magnetic field impression means to impress the mutually different 1st of a direction and the 2nd mutually different magnetic field to the above-mentioned magneto optics crystal. The above 1st and the 2nd magnetic field are sufficient strength for these synthetic magnetic fields to saturate magnetization of the above-mentioned magneto optics crystal including a magnetic field adjustment means to change either [at least] the above 1st or the 2nd magnetic field.

[Claim 17] It is the optical attenuator which is an optical attenuator according to claim 16, and intersects perpendicularly mutually on the above 1st and a flat surface with the direction parallel to the above-mentioned optical path of the 2nd magnetic field.

[Claim 18] It is the optical attenuator to which it is an optical attenuator according to claim 16, the above-mentioned magnetic field impression means is the electromagnet and permanent magnet which impress the above 1st and the 2nd magnetic field, respectively, and the above-mentioned magnetic field adjustment means adjusts the drive current of the above-mentioned electromagnet.

[Claim 19] It is an optical attenuator according to claim 18, and the direction of the 2nd magnetic field of the above is [the above-mentioned optical path and] an parallel optical attenuator substantially.
[Claim 20] It is the optical attenuator which controls each Faraday-rotation angle by the bottom of the conditions to which it is an optical attenuator according to claim 1, and, as for the above-mentioned means which carries out control, the Faraday-rotation angle of the attenuator unit of the above 1st and the Faraday-rotation angle of the attenuator unit of the above 2nd become equal substantially.
[Claim 21] Are an optical attenuator according to claim 1, and the above-mentioned means which carries out control Each Faraday-rotation angle is controlled by the bottom of the conditions to which the Faraday-rotation angle of the attenuator unit of the above 1st and the Faraday-rotation angle of the attenuator unit of the above 2nd become equal substantially when attenuation of the above-mentioned optical attenuator is comparatively large. The optical attenuator which controls each Faraday-rotation angle by the bottom of the conditions from which the Faraday-rotation angle of the attenuator unit of the above 1st and the Faraday-rotation angle of the attenuator unit of the above 2nd differ when attenuation of the above-mentioned optical attenuator is comparatively small.
[Claim 22] The optical attenuator characterized by providing the following. The 1st and the 2nd attenuator unit by which the cascade connection was carried out on the optical path. this -- the Faraday-rotation child for producing the Faraday-rotation angle which it has the control circuit connected to the 1st and 2nd attenuator units, and each of the above 1st and the 2nd attenuator unit is arranged on the above-mentioned optical path, and is given as a function of wavelength The above-mentioned control circuit is a means control each above-mentioned Faraday-rotation angle so that the wavelength property given as the sum of the wavelength property of the attenuation in the attenuator unit of the above 1st and the wavelength property of the attenuation in the attenuator unit of the above 2nd has a desired inclination, including the polarization means for producing the attenuation determined according to the above-mentioned Faraday-rotation angle about the above-mentioned optical path.
[Claim 23] the 1st for giving each adjustable attenuation, and the 2nd attenuator unit -- having -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- a different optical attenuator from the 2nd wavelength property of attenuation of the 2nd attenuator unit
[Claim 24] It is the optical attenuator with which it is an optical attenuator according to claim 23 and the wavelength property of the above 2nd denies the wavelength property of the above 1st substantially.
[Claim 25] they are the optical transmission line to which the wavelength division multiplex light containing two or more lightwave signals which have mutually different wavelength is transmitted, and this optical transmission line -- on the way -- the 1st for it being alike, being prepared and giving each adjustable attenuation, and the 2nd attenuator unit -- having -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- a different system from the 2nd wavelength property of attenuation of the 2nd attenuator unit
[Claim 26] It is the system by which it is a system according to claim 25, and the wavelength property of the above 2nd negates the wavelength property of the above 1st substantially.
[Claim 27] the 1st optical-amplification unit and the 2nd optical-amplification unit -- this -- the 1st for being prepared between the 1st and 2nd optical-amplification units, and giving each adjustable attenuation, and the 2nd attenuator unit -- having -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- a different light amplifier from the 2nd wavelength property of attenuation of the 2nd attenuator unit
[Claim 28] It is the light amplifier with which it is a light amplifier according to claim 27 and the wavelength property of the above 2nd denies the wavelength property of the above 1st substantially.
[Claim 29] It is the light amplifier which negates substantially the wavelength property of light that are a light amplifier according to claim 27, and the above 1st and the 2nd wavelength property are outputted from the optical-amplification unit of the above 2nd.
[Claim 30] the 1st for having an optical-amplification unit and the optical attenuator connected to the output of this optical-amplification unit, and this optical attenuator giving each adjustable attenuation, and the 2nd attenuator unit -- having -- **** -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- a different light amplifier from the 2nd wavelength property of attenuation of the 2nd attenuator unit
[Claim 31] It is the light amplifier with which it is a light amplifier according to claim 30 and the wavelength property of the above 2nd denies the wavelength property of the above 1st substantially.
[Claim 32] the 1st for having an optical-amplification unit and the optical attenuator connected to the input of this optical-amplification unit, and this optical attenuator giving each adjustable attenuation, and the 2nd attenuator unit -- having -- **** -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- a different light amplifier from the 2nd wavelength property of attenuation of the 2nd attenuator unit
[Claim 33] It is the light amplifier with which it is a light amplifier according to claim 32 and the wavelength property of the above 2nd denies the wavelength property of the above 1st substantially.

[Claim 34] Two or more E/O converters which output the lightwave signal which has different wavelength, respectively, Two or more level adjustment units for adjusting the level of the lightwave signal from two or more of these E/O converters, It has an optical multiplexer for carrying out the wavelength division multiplex of the lightwave signal outputted from two or more of these level adjustment units, and obtaining wavelength division multiplex light. each of two or more above-mentioned level adjustment units the 1st for giving each adjustable attenuation, and the 2nd attenuator unit -- having -- **** -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- different terminal equipment from the 2nd wavelength property of attenuation of the 2nd attenuator unit

[Claim 35] Two or more E/O converters which output the lightwave signal which has different wavelength, respectively, Two or more level adjustment units for adjusting the level of the lightwave signal from two or more of these E/O converters, The optical multiplexer for carrying out the wavelength division multiplex of the lightwave signal outputted from two or more of these level adjustment units, and obtaining wavelength division multiplex light, It has a light amplifier for amplifying the wavelength division multiplex light outputted from this optical multiplexer. this light amplifier It has the optical-amplification unit and the optical attenuator connected to this optical-amplification unit. this optical attenuator the 1st for giving each adjustable attenuation, and the 2nd attenuator unit -- having -- **** -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- different terminal equipment from the 2nd wavelength property of attenuation of the 2nd attenuator unit

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[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] this invention relates to the system, the light amplifier, and terminal equipment which were especially equipped with the optical attenuator and this optical attenuator about the optical attenuator equipped with two Faraday-rotation children.
[0002]
[Description of the Prior Art] An optical attenuator may be used, in order to adjust the power of the light supplied to optical devices, such as a light amplifier, when building an optical transmission system. There is a thing to which it was made to change attenuation by mechanical operation conventionally as this kind of an optical attenuator. For example, the distribution is given to attenuation of the attenuation film inserted into an optical path, and attenuation is adjusted by carrying out the variation rate of this attenuation film mechanically.
[0003] To use it, including an optical attenuator in a system by which the attenuation is set as the object of control may be demanded practically. For example, in erbium dope fiber amplifier (EDFA), in order to maintain a fixed output level, the once amplified lightwave signal is supplied to the optical attenuator for giving the attenuation in which feedback control was carried out by the monitor value of an output level. In such a case, use of the optical attenuator which adjusts attenuation mechanically is not desirable in order to raise the reliability of a system.
[0004] In view of this point, this invention person proposed the optical attenuator excellent in the practicality which does not have a mechanical movable portion previously (for example, Japanese Patent Application No. No. 205044 [four to]). This optical attenuator is equipped with the Faraday-rotation child from whom a Faraday-rotation angle changes with change of force current on an electromagnet, and attenuation is set up by regulation of a Faraday-rotation angle.
[0005]
[Problem(s) to be Solved by the Invention] As for an optical attenuator, it is desirable to give attenuation uniform irrespective of the wavelength to the light inputted. When the Faraday-rotation child has the wavelength property (i.e., when a Faraday-rotation angle changes depending on wavelength), attenuation changes according to wavelength and the wavelength property of attenuation becomes however, less flat. If the optical attenuator whose wavelength property of attenuation is not flat is applied to a wavelength division multiplex system, it will become that from which attenuation of a lightwave signal differs for every channel, and un-arranging, such as deflection between channels of signal power, will arise. moreover -- for example, in order to cancel the gain inclination (property in which gain changes according to wavelength) produced in EDFA, there is also demand that he may want to set up the wavelength property of attenuation of an optical attenuator arbitrarily
[0006] Therefore, the purpose of this invention is to offer an optical attenuator with the flat wavelength property of attenuation. Other purposes of this invention are to offer the optical attenuator which can adjust the wavelength property of attenuation.
[0007] The purpose of further others of this invention is to offer a system, a light amplifier, and terminal equipment equipped with such an optical attenuator.
[0008]
[Means for Solving the Problem] According to the 1st side of this invention, the optical attenuator equipped with the control circuit connected to the 1st and 2nd attenuator units by which the cascade connection was carried out on the optical path, and the 1st and 2nd attenuator units is offered. Each of the 1st and 2nd attenuator units contains the Faraday-rotation child stationed on an optical path. A Faraday-rotation child produces the Faraday-rotation angle given as a function of wavelength. Each of the 1st and 2nd attenuator units includes the polarization means for producing further the attenuation determined according to a Faraday-rotation angle about an optical path. Especially, in the

optical attenuator by this side of this invention, a control circuit includes a means to control each Faraday-rotation angle so that the wavelength property of the attenuation in the 1st attenuator unit is substantially offset by the wavelength property of the attenuation in the 2nd attenuator unit.

[0009] Although each Faraday-rotation child is producing the Faraday-rotation angle given as a function of wavelength according to this composition, when a control circuit operates, flattening of the wavelength property of total attenuation is carried out substantially.

[0010] In the optical attenuator by the 2nd side of this invention, a control circuit includes a means to control each Faraday-rotation angle so that the wavelength property given as the sum of the wavelength property of the attenuation in the 1st attenuator unit and the wavelength property of the attenuation in the 2nd attenuator unit has a desired inclination. Thereby, the wavelength property of attenuation can be freely adjusted now.

[0011] the 1st for giving each adjustable attenuation according to the 3rd side of this invention, and the 2nd attenuator unit -- having -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- a different optical attenuator from the 2nd wavelength property of attenuation of the 2nd attenuator unit is offered

[0012] according to the 4th side of this invention, they are the optical transmission line to which the wavelength division multiplex light containing two or more lightwave signals which have mutually different wavelength is transmitted, and this optical transmission line -- on the way -- the 1st for it being alike, being prepared and giving each adjustable attenuation, and the 2nd attenuator unit -- having -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- a different system from the 2nd wavelength property of attenuation of the 2nd attenuator unit is offered

[0013] according to the 5th side of this invention -- the 1st optical-amplification unit and the 2nd optical-amplification unit -- this -- the 1st for being prepared between the 1st and 2nd optical-amplification units, and giving each adjustable attenuation, and the 2nd attenuator unit -- having -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- a different light amplifier from the 2nd wavelength property of attenuation of the 2nd attenuator unit is offered

[0014] the 1st for according to the 6th side of this invention, having an optical-amplification unit and the optical attenuator connected to the output of this optical-amplification unit, and this optical attenuator giving each adjustable attenuation, and the 2nd attenuator unit -- having -- **** -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- a different light amplifier from the 2nd wavelength property of attenuation of the 2nd attenuator unit is offered

[0015] the 1st for according to the 7th side of this invention, having an optical-amplification unit and the optical attenuator connected to the input of this optical-amplification unit, and this optical attenuator giving each adjustable attenuation, and the 2nd attenuator unit -- having -- **** -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- a different light amplifier from the 2nd wavelength property of attenuation of the 2nd attenuator unit is offered

[0016] Two or more E/O converters which output the lightwave signal which has different wavelength according to the side of the octavus of this invention, respectively, Two or more level adjustment units for adjusting the level of the lightwave signal from two or more of these E/O converters, It has an optical multiplexer for carrying out the wavelength division multiplex of the lightwave signal outputted from two or more of these level adjustment units, and obtaining wavelength division multiplex light. each of two or more above-mentioned level adjustment units the 1st for giving each adjustable attenuation, and the 2nd attenuator unit -- having -- **** -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- different terminal equipment from the 2nd wavelength property of attenuation of the 2nd attenuator unit is offered

[0017] Two or more E/O converters which output the lightwave signal which has different wavelength according to the 9th side of this invention, respectively, Two or more level adjustment units for adjusting the level of the lightwave signal from two or more of these E/O converters, The optical multiplexer for carrying out the wavelength division multiplex of the lightwave signal outputted from two or more of these level adjustment units, and obtaining wavelength division multiplex light, It has a light amplifier for amplifying the wavelength division multiplex light outputted from this optical multiplexer. this light amplifier It has the optical-amplification unit and the optical attenuator connected to this optical-amplification unit. this optical attenuator the 1st for giving each adjustable attenuation, and the 2nd attenuator unit -- having -- **** -- this -- the 1st wavelength property of attenuation of the 1st attenuator unit -- this -- different terminal equipment from the 2nd wavelength property of attenuation of the 2nd attenuator unit is offered

[0018]

[Embodiments of the Invention] Hereafter, with reference to an accompanying drawing, the gestalt of desirable operation of this invention is explained in detail. The same sign is substantially given to the same portion through the complete diagram, and when a direction and others need to be specified, the three-dimensions system of coordinates by

the X-axis, the Y-axis, and the Z-axis which intersect perpendicularly mutually are adopted.
[0019] Drawing 1 is drawing showing the 1st operation gestalt of the optical attenuator by this invention. This optical attenuator is equipped with two attenuator units AU1 and AU2 by which the cascade connection was carried out on the optical path OP parallel to the Z-axis, and the control circuit 2 connected to units AU1 and AU2.
[0020] Each of the attenuator units AU1 and AU2 contains the polarization unit PU for producing the attenuation determined according to the Faraday-rotation child FR and Faraday-rotation angle for giving an adjustable Faraday-rotation angle to the light spread along with an optical path OP.
[0021] With this operation gestalt, especially the polarization unit PU of the attenuator unit AU1 consists of polarizers 4 and 6 formed on an optical path OP so that the Faraday-rotation child FR may be inserted, and the polarization unit PU of the attenuator unit AU2 consists of polarizers 8 and 10 formed on an optical path OP so that the Faraday-rotation child FR may be inserted. Polarizers 4, 6, 8, and 10 have the shafts 4A, 6A, 8A, and 10A which determine the plane of polarization of the linearly polarized light which passes respectively, respectively. Here, shaft 4A is parallel to a Y-axis, and Shafts 6A, 8A, and 10A are parallel to the X-axis.
[0022] Operation of the optical attenuator of drawing 1 is explained briefly first. When the Faraday-rotation angle given by the Faraday-rotation child FR of the attenuator unit AU1 is 90 degrees Since Shafts 4A and 6A lie at right angles mutually, attenuation of the attenuator unit AU1 becomes the minimum. moreover, when the Faraday-rotation angle given by the Faraday-rotation child FR of the attenuator unit AU2 is 0 degree Since Shafts 8A and 10A are mutually parallel, attenuation of the attenuator unit AU2 becomes the minimum, therefore the total attenuation by this optical attenuator becomes the minimum.
[0023] Here, a 0-degree Faraday-rotation angle contains [saying / a 90-degree Faraday-rotation angle / and] m.180 degrees (m is an integer) in a wide sense including 90 degrees +n.180 degrees (n is an integer).
[0024] When the Faraday-rotation angle on which the Faraday-rotation angle given by the Faraday-rotation child FR of the attenuator unit AU1 is given to 0 degree by near and the Faraday-rotation child FR of the attenuator unit AU2 is close to 90 degrees, the total attenuation by this optical attenuator serves as the maximum.
[0025] Reference of drawing 2 shows each Faraday-rotation child's FR example of concrete composition. The Faraday-rotation child FR has the magneto optics crystal 12 prepared so that an optical path OP may pass.
[0026] If the linearly polarized light passes through the inside of a magneto optics crystal 12 where it is in the state which generally impressed the magnetic field in a magneto optics crystal 12, namely, a magneto optics crystal 12 is set in a certain magnetic field, the polarization direction will be rotated to the always same hand of cut irrespective of the propagation direction.
[0027] Here, the "polarization direction" is defined by the projection to a flat surface perpendicular to the propagation direction of the flat surface containing the electric field vector of the linearly polarized light. The phenomenon which this polarization direction rotates is called Faraday rotation, and it depends for the size (Faraday-rotation angle) of the angle of rotation of the polarization direction on the direction and strength (size) of magnetization which are produced by the impression magnetic field. [a magneto optics crystal 12] Specifically, a Faraday-rotation angle is determined by the size of the component of the propagation direction of the light of the intensity of magnetization of a magneto optics crystal 12.
[0028] Therefore, if a means to impress a magnetic field in the same direction as the propagation direction of light to a magneto optics crystal 12 and a crystal 12 is used and it will glance by adjusting the impression magnetic field, the Faraday-rotation angle is adjusted effectively. However, the point which should be taken into consideration here is that magnetization of the magneto optics crystal 12 by the impression magnetic field does not reach a saturation state, but many magnetic domains exist in a magneto optics crystal 12, when the size of an impression magnetic field is comparatively small.
[0029] Such existence of many magnetic domains worsens the repeatability of a Faraday-rotation angle, and though good repeatability is secured, it makes adjustable [**** / a Faraday-rotation angle] difficult. Moreover, when many magnetic domains exist in a magneto optics crystal 12, attenuation by dispersion of the light in the interface between magnetic domains is also produced, and it becomes inconvenient [on practical use].
[0030] Then, by making it impress the mutually different 1st of a direction and the 2nd mutually different magnetic field to a magneto optics crystal 12 with this operation gestalt, and changing at least one side of the 1st and 2nd magnetic fields, it is made for the Faraday-rotation angle acquired to change, and it has set up so that it may have sufficient strength for these synthetic magnetic fields to saturate the intensity of magnetization of a magneto optics crystal 12 in the 1st and 2nd magnetic fields.
[0031] The magnetic domain of a crystal 12 can understand the state where intensity of magnetization was saturated in the magneto optics crystal 12, as a state set to one. By changing at least one side of the 1st and 2nd magnetic fields in the state where magnetization of a magneto optics crystal 12 is saturated, adjustable [**** / a Faraday-rotation angle]

becomes possible, and generating of loss resulting from dispersion of the light in the interface between magnetic domains can be prevented. Moreover, the repeatability of a Faraday-rotation angle also becomes good.

[0032] Since desirably makes possible adjustable [with an effective Faraday-rotation angle], it is impressed in the direction which intersects perpendicularly mutually within a flat surface parallel to an optical path OP by the 1st and 2nd magnetic fields, respectively.

[0033] With the operation gestalt of drawing 2 , in order to be prepared so that the permanent magnet 14 of a couple may face across the vertical side of a magneto optics crystal 12, in order to impress the fixed field system FM parallel to the Z-axis (refer to drawing 1) to a magneto optics crystal 12, and to impress the adjustable magnetic field VM parallel to the X-axis (refer to drawing 1) to a magneto optics crystal 12, it is prepared so that the left and right laterals of an electromagnet 16 of a magneto optics crystal 12 may be pinched. The coil 18 of an electromagnet 16 is connected to the source 20 of a good transformation style. By adjusting the drive current supplied to an electromagnet 16 by the source 20 of a good transformation style, the direction of magnetization of a magneto optics crystal 12 changes, and a Faraday-rotation angle changes in connection with it.

[0034] As a magneto optics crystal 12, YIG (yttrium iron garnet) started thinly and the 3 (GdBi) 5 (FeAlGa) O12 grade which carried out the epitaxial crystal growth can be used.

[0035] With the operation gestalt of drawing 2 , a fixed field system FM is impressed to an optical path OP and parallel, and the adjustable magnetic field VM is impressed at right angles to an optical path OP because there is demand of impression of the magnetic field to a direction perpendicular to an optical path OP being easy as compared with impression of the magnetic field to a direction parallel to an optical path OP, and wanting to apply the electromagnet 16 with complicated composition to the easier one.

[0036] Drawing 3 is drawing for explaining the principle from which a Faraday-rotation angle changes by the Faraday-rotation child FR shown in drawing 2 . In order to indicate the direction and strength of magnetization by the vector, the vertical axis and horizontal axis of drawing 3 correspond to the Z-axis and the X-axis, respectively. [the magnetic field impressed to a magneto optics crystal 12, and a crystal 12]

[0037] Now, the drive current of an electromagnet 16 is 0 substantially, and when the fixed field system FM is impressed to the magneto optics crystal 12 only with the permanent magnet 14, magnetization of a crystal 12 becomes parallel to the Z-axis, as shown by the sign 22. The strength of a fixed field system FM is set up so that magnetization of a crystal 12 may be saturated with a fixed field system FM. When the fixed field system FM is impressed, it is made for a Faraday-rotation angle to become 90 degrees with this operation gestalt.

[0038] If the adjustable magnetic field VM by the electromagnet 16 is impressed to the X-axis and parallel, a synthetic magnetic field will be given by the synthetic vector of a fixed field system FM and the adjustable magnetic field VM, as shown by the sign 24. Magnetization as shown in a magneto optics crystal 12 with a sign 26 by this synthetic magnetic field 24 arises. The direction of magnetization 26 and the direction of the synthetic magnetic field 24 are mutually parallel, and since magnetization of a magneto optics crystal 12 is saturated, the strength (the length of a magnetization vector) of magnetization 26 is in agreement with the strength (the length of a magnetization vector) of magnetization 22.

[0039] The degree of contribution of the magnetization to the Faraday-rotation angle in a crystal 12 is not the same just because the intensity of magnetization of a magneto optics crystal 12 is fixed. It is because a Faraday-rotation angle is dependent also on the relation between the direction of the magnetization concerned, and the propagation direction of light.

[0040] That is, if the state where the state where magnetization 22 has arisen, and magnetization 26 have arisen is compared, only in the part to which the Z-axis component 28 of magnetization 26 is decreasing to the Z-axis component (magnetization 22 itself) of magnetization 22, the latter Faraday-rotation angle will become small.

[0041] Specifically by the Faraday-rotation child FR shown in drawing 2 , the Faraday-rotation angle becomes small toward 90 to 0 degree by changing the drive current of a permanent magnet 16 from 0 to maximum.

[0042] Drawing 4 is a graph which shows the relation of the attenuation and the drive current of an electromagnet 16 in each of the attenuator units AU1 and AU2 shown in drawing 1 . In the attenuator unit AU1, since it is impressed in the direction in which Shafts 4A and 6A are mutually perpendicular, and the adjustable magnetic field VM by the electromagnet 16 is perpendicular to the Z-axis, according to drive current increasing, attenuation increases continuously.

[0043] On the other hand, in the attenuator unit AU2, Shafts 8A and 10A are mutually parallel, and since the adjustable magnetic field VM by the permanent magnet 16 is impressed to the Z-axis and the perpendicular, according to the drive current of an electromagnet 16 increasing, attenuation decreases continuously.

[0044] The principle to which the wavelength property of attenuation becomes flat with the combination of such two attenuator units AU1 and AU2 is explained below. Drawing 5 is a graph which shows an example of the wavelength

property of the Faraday-rotation angle when saturating magnetization of a certain magneto optics crystal. The wavelength (micrometer) of the light [angle / Faraday-rotation / (deg/cm)] to which a vertical axis is given to and, as for a horizontal axis, a Faraday-rotation angle is given is shown. In the example of this magneto optics crystal, the Faraday-rotation angle per unit length is decreasing as wavelength becomes long.

[0045] The influence of the wavelength property of each Faraday-rotation angle in the optical attenuator of drawing 1 is explained that the magneto optics crystal 12 has a property like drawing 5 with reference to drawing 6 . Wavelength lambda 2 now supplied to the attenuator unit AU1 Suppose that the drive current of an electromagnet 16 is set up so that the Faraday-rotation angle given to light may become 45 degrees. In this case, wavelength lambda 2 Long wave length lambda 1 The Faraday-rotation angle given to light becomes smaller than 45 degrees, and is wavelength lambda 2. Short wavelength lambda 3 The Faraday-rotation angle given to light becomes larger than 45 degrees.

[0046] Since attenuation increases in the attenuator unit AU1 as a Faraday-rotation angle approaches 0 degree from 90 degrees, it is wavelength lambda 1 and lambda 2. And lambda 3 It is attenuation of the attenuator unit AU1 to light, respectively a1 (dB) and a2 (dB) and a3 When (dB), it is a3 <a2 <a1. It becomes.

[0047] On the other hand, since attenuation becomes small in the attenuator unit AU2 as a Faraday-rotation angle approaches 0 degree from 90 degrees, the wavelength property of a Faraday-rotation angle sets in the linear range substantially, and it is wavelength lambda 1 and lambda 2. And lambda 3 Attenuation of the attenuator unit 2 to light is a3, respectively. (dB) and a2 (dB) and a1 It is set to (dB).

[0048] thus, as the wavelength property of a Faraday-rotation angle is shown in drawing 5 , when it has the negative inclination In the attenuator unit AU1 to which it is made for attenuation to increase according to the drive current of an electromagnet 16 increasing Attenuation becomes large as wavelength becomes long, and in the attenuator unit AU2 to which it is made for attenuation to decrease on the other hand according to the drive current of an electromagnet 16 increasing, attenuation becomes small as wavelength becomes long.

[0049] (A) of drawing 7 and (B) are drawings showing change of the wavelength property of the attenuation in the attenuator units AU1 and AU2, respectively. The inclination for the lower right to become [the wavelength property of attenuation] ** is strong as the inclination for the wavelength property of attenuation to become an upward slant to the right is strong, and are shown in (A) of drawing 7 , the drive current of an electromagnet 16 becomes large, it is shown in (B) of drawing 7 , if it is in the attenuator unit AU2 on the other hand and drive current becomes small, if it is in the attenuator unit AU1.

[0050] When the Faraday-rotation angle in the attenuator unit AU1 is set to thetaF1, attenuation (dB) of the attenuator unit AU1 is 10 and log [sin2 thetaF1].

It is come out and given. Therefore, change of transmitted light power when wavelength deltalambda Increases is -sin2thetaF1sin (KthetaF1deltalambda).

It becomes. Here, K is a coefficient at the time of approximating the wavelength property of a Faraday-rotation angle primarily.

[0051] On the other hand, when the Faraday-rotation angle in the attenuator unit AU2 is set to thetaF2, attenuation (dB) of the attenuator unit AU2 is 10 and log [sin2] (90 degree-thetaF2).

It is come out and given. Therefore, change of transmitted light power when wavelength deltalambda Increases is sin2thetaF2sin (KthetaF2deltalambda).

It becomes. Therefore, the group of combination which gives the solution of the equation shown below (thetaF1, thetaF2) gives the conditions against which the wavelength property of the attenuation in the attenuator unit AU1 is substantially set off by the wavelength property of the attenuation in the attenuator unit AU2.

[0052] The wavelength property of total attenuation of an optical attenuator shown in drawing 1 can be made flat by controlling each Faraday-rotation angle by the bottom of the conditions to which sin2thetaF1sin(KthetaF1deltalambda) +sin2thetaF2sin(KthetaF2deltalambda) =0, for example, the Faraday-rotation angle in the attenuator unit AU1, and the Faraday-rotation angle in the attenuator unit AU2 become equal substantially.

[0053] or when total attenuation is comparatively large (for example, when the sum of attenuation above two nodes shown in drawing 4 serves as total attenuation) Each Faraday-rotation angle is controlled by the bottom of the conditions to which the Faraday-rotation angle in the attenuator unit AU1 and the Faraday-rotation angle in the attenuator unit AU2 become equal substantially. On the other hand, when total attenuation is comparatively small (for example, when the sum of attenuation below this intersection serves as total attenuation) You may make it control each Faraday-rotation angle by the bottom of the conditions from which the Faraday-rotation angle in the attenuator unit AU1 and the Faraday-rotation angle in the attenuator unit AU2 differ.

[0054] The example of composition of the control circuit 2 suitable for performing control which was rich in such flexibility is shown in drawing 8 . Drawing 8 is the block diagram showing the operation gestalt of a control circuit 2. Here, the control circuit 2 is equipped with CPU (central arithmetic unit)30 for performing the operation for

determining the drive current of each electromagnet 16 based on the control input for giving desired attenuation etc., RAM (RAM)32 for memorizing the data about the result of an operation etc. temporarily, ROM (read only memory)34 a program, data, etc. required for an operation are remembered to be, and I/O Port 36 for I/O of data. CPU30, RAM32, ROM34, and I/O Port 36 are mutually connected by the data bus 38.

[0055] The data table showing the relation between the group of the solution of the above-mentioned equation obtained beforehand and the attenuation obtained by the solution concerned is stored in ROM34. If desired total attenuation is given by the control input, the solution for obtaining the attenuation will be chosen by CPU30, and the Faraday-rotation angle in the attenuator units AU1 and AU2 will be set up so that the solution may be satisfied. The digital data outputted from I/O Port 36 is specifically changed into the control signal of an analog by D/A converters 40 and 42, respectively, and each control signal is supplied to each source 20 of a good transformation style of the attenuator units AU1 and AU2. Thereby, the drive current of each electromagnet 16 is set up and combination of a Faraday-rotation angle from which desired attenuation is obtained is performed.

[0056] For example, in making total attenuation small, while an electromagnet 16 drives in a field in which the Faraday-rotation angle in the attenuator unit AU1 becomes 90 degrees closely, an electromagnet 16 drives in a field with the Faraday-rotation angle near 0 degree in the attenuator unit AU2.

[0057] Thus, since it is made according to this operation gestalt for a control circuit 2 to control each Faraday-rotation angle so that the wavelength property of the attenuation in the attenuator unit AU1 is substantially offset by the wavelength property of the attenuation in the attenuator unit AU2, the wavelength property of total attenuation can be made flat.

[0058] Drawing 9 is drawing showing the 2nd operation gestalt of the optical attenuator by this invention. This operation gestalt is characterized in that replace with the Faraday-rotation child FR and polarizer 10 of the attenuator unit AU2 in the 1st operation gestalt of drawing 1 , and Faraday-rotation child FR' and polarizer 10' which were changed are used. Although the internal configuration of Faraday-rotation child FR' does not illustrate, it is changed so that the adjustable magnetic field VM may be set as an optical path OP and parallel and a fixed field system FM may be set as an optical path OP and a perpendicular. Moreover, polarizer 10' has shaft 10A' parallel to a Y-axis. Since attenuation by the attenuator unit AU2 decreases according to the drive current of the electromagnet in the attenuator unit AU2 increasing also by this composition, according to the principle same in the 1st operation gestalt of drawing 1 , the wavelength property of the attenuation in the attenuator unit AU1 is substantially offset by the wavelength property of the attenuation in the attenuator unit AU2, and can make the wavelength property of total attenuation flat with it.

[0059] Drawing 10 is drawing showing the 3rd operation gestalt of the optical attenuator by this invention. This operation gestalt is characterized in that replace with the polarizer 10 of the attenuator unit AU2 in the 1st operation gestalt of drawing 1 , and changed polarizer 10' is used. Polarizer 10' has shaft 10A' parallel to a Y-axis.

[0060] Shaft 8A and 10A' lies at right angles mutually, a shaft A4 and 6A also lie at right angles mutually, and since the Faraday-rotation child FR of the attenuator units AU1 and AU2 is the same, the attenuator units AU1 and AU2 operate similarly.

[0061] That is, in each of the attenuator units AU1 and AU2, attenuation increases according to the drive current of an electromagnet 16 increasing. Moreover, in each of the attenuator units AU1 and AU2, the inclination for the wavelength property of attenuation to become an upward slant to the right becomes strong as are shown in (A) of drawing 7 and drive current becomes large.

[0062] Therefore, operation of a control circuit 2 can be changed and a setup whose wavelength property given as the sum of the wavelength property of the attenuation in the attenuator unit AU1 and the wavelength property of the attenuation in the attenuator unit AU2 has a desired inclination can be performed. That is, according to this operation gestalt, the wavelength property of total attenuation can be easily adjusted now. Moreover, since the cascade connection of the two attenuator units AU1 and AU2 which operate similarly is carried out, the dynamic range of regulation of the wavelength property of total attenuation becomes large.

[0063] Although polarizers 6 and 8 are illustrated as another member with the operation gestalt explained above in order to make easy the composition of the attenuator units AU1 and AU2, and an understanding of operation, since Shafts 6A and 8A are mutually parallel, they may omit either of the polarizers 6 and 8. Moreover, a polarizer 4 can also be omitted when it is the case where this optical attenuator is used as light passes the attenuator units AU1 and AU2 in this order along with an optical path OP, and it is the linearly polarized light in which the input light to the attenuator unit AU1 has plane of polarization parallel to YZ flat surface.

[0064] Hereafter, some operation gestalten with the desirable this invention excellent in practicality are explained. Here, it is prevented by the combination of a specific birefringence crystal, and optical arrangement that attenuation is dependent on the polarization state of input light.

[0065] Drawing 11 is drawing showing the 4th operation gestalt of the optical attenuator by this invention. This

operation gestalt is characterized in that the wedge boards 44, 46, 48, and 50 which replace with the polarizers 4, 6, 8, and 10 shown in drawing 1 , and consist of a birefringence crystal respectively are formed, respectively. Moreover, the optical fiber 52 for an input light beam and the lens 54, the lens 56 for combining optically the attenuator units AU1 and AU2, an optical fiber 58 and a lens 60, the lens 62 for an output light beam, and the optical fiber 64 are formed additionally.

[0066] The optical path which the optical path which combines between an optical fiber 52 and 58 is offered by the ordinary ray and extraordinary ray by which each of the wedge boards 44 and 46 is defined, and combines between an optical fiber 58 and 64 is offered by the ordinary ray and extraordinary ray by which each of the wedge boards 48 and 50 is defined.

[0067] According to this composition, the attenuation in the optical path which the attenuation in the optical path which combines between an optical fiber 52 and 58 is determined by the Faraday-rotation angle in the Faraday-rotation child FR of the attenuator unit AU1, and combines between optical Faraday 58 and 64 is determined by the Faraday-rotation angle in the Faraday-rotation child FR of the attenuator unit AU2. Therefore, the optical fiber 64 for an output will be optically combined at the joint efficiency according to each Faraday-rotation angle to the optical fiber 52 for an input, and desired total attenuation comes to be obtained.

[0068] Each of the wedge boards 44 and 46 has the wedge angle defined on the 1st flat surface, and each of the wedge boards 48 and 50 has the wedge angle defined on the 2nd flat surface. With this operation gestalt, especially the 1st and 2nd flat surfaces are parallel to YZ flat surface.

[0069] The wedge boards 44 and 46 have the main shafts 44A and 46A for determining an ordinary ray and an extraordinary ray respectively, respectively. Moreover, the wedge boards 48 and 50 have the main shafts 48A and 50A for determining an ordinary ray and an extraordinary ray respectively, respectively. With this operation gestalt, especially main shaft 44A is parallel to the X-axis, and main shafts 46A, 48A, and 50A are parallel to a Y-axis.

[0070] The wedge boards 44 and 46 are the same configurations, and these are arranged so that the fields to which the crowning and pars basilaris ossis occipitalis of the wedge board 44 counter and correspond to the pars basilaris ossis occipitalis and crowning of the wedge board 46, respectively may become parallel mutually. Moreover, the wedge boards 48 and 50 are also the same configurations, and these are arranged so that the fields to which the crowning and pars basilaris ossis occipitalis of the wedge board 48 counter and correspond to the pars basilaris ossis occipitalis and crowning of the wedge board 50, respectively may become parallel mutually.

[0071] The light emitted from fiber edge 52A of an optical fiber 52 is collimated by the lens 54, and becomes an parallel light beam. This beam disregards a beam size and is expressed with a sign 102. A beam 102 is divided into the beam 104 which is equivalent to the ordinary ray in the wedge board 44, and the beam 106 equivalent to an extraordinary ray.

[0072] Faraday rotation only of the same Faraday-rotation angle is carried out to the same direction by the Faraday-rotation child FR, and beams 104 and 106 turn into beams 108 and 110, respectively. A beam 108 is divided into the beam 112 which is equivalent to the ordinary ray in the wedge board 46, and the beam 114 equivalent to an extraordinary ray. A beam 110 is divided into the beam 116 which is equivalent to the extraordinary ray in the wedge board 46, and the beam 118 equivalent to an ordinary ray.

[0073] If beams 112,114,116 and 118 take into consideration the configuration and arrangement gestalt of the history of refraction and the wedge boards 44 and 46 which have received, respectively, beams 112 and 116 are mutually parallel, and that of beams 114 and 118 are not mutually parallel.

[0074] Therefore, the parallel beams 112 and 116 of each other can be completed with a lens 56, incidence can be carried out to an optical fiber 58 from fiber edge 58A of one of these, and at this time, the beams 114 and 118 which are not parallel swerve from an optical path, and each other do not carry out incidence to fiber edge 58A.

[0075] Now, the attenuation in the attenuator unit AU1 corresponds to the ratio to the power of the beam 102 of the total power of beams 112 and 116. For example, since the power of a beam 104 all shifts to the power of 112 theoretically and the power of a beam 106 all shifts to the power of a beam 116 theoretically when the Faraday-rotation child's FR Faraday-rotation angle is 90 degrees, attenuation of the attenuator unit AU1 becomes the smallest. Moreover, since the power of a beam 104 all shifts to the power of a beam 114 theoretically and the power of a beam 106 all shifts to the power of a beam 118 theoretically when the Faraday-rotation child's FR Faraday-rotation angle is 0 degree, attenuation of the attenuator unit AU1 becomes the largest. Therefore, in the attenuator unit AU1, the attenuation according to the Faraday-rotation angle of the Faraday-rotation angle FR will be obtained.

[0076] On the other hand, if the Faraday-rotation angle is fixed, since the total power of beams 112 and 116 is fixed irrespective of the polarization state of a beam 102, the attenuation in the attenuator unit AU1 is not dependent on the polarization state of a beam 102 (namely, input beam).

[0077] Then, the light which carried out incidence to fiber edge 58A of an optical fiber 58 is emitted from fiber edge

58B of another side of an optical fiber 58, and this light is collimated by the lens 60 and becomes an parallel light beam. This beam disregards a beam size and is expressed with a sign 122.
[0078] A beam 122 is divided into the beam 124 which is equivalent to the ordinary ray in the wedge board 48, and the beam 126 equivalent to an extraordinary ray. In the Faraday-rotation child FR of the attenuator unit AU2, Faraday rotation of the beams 124 and 126 is carried out to the same direction on the same Faraday-rotation square, and they turn into beams 128 and 130, respectively.
[0079] A beam 128 is divided into the beam 132 which is equivalent to the ordinary ray in the wedge board 50, and the beam 134 equivalent to an extraordinary ray. A beam 130 is divided into the beam 136 which is equivalent to the extraordinary ray in the wedge board 50, and the beam 138 equivalent to an ordinary ray.
[0080] If it thinks in the attenuator unit AU1 the same way, incidence of the beams 132 and 136 is carried out to fiber edge 64A of an optical fiber 64, beams 134 and 138 will swerve from an optical path, and they will not carry out incidence to fiber edge 64A.
[0081] Similarly in the attenuator unit AU1 the attenuation by the attenuator unit AU2 is not dependent on the polarization state of an input beam (beam 122). However, since main shaft 48A and main shaft 50A are mutually parallel to main shafts 44A and 46A being mutually perpendicular, the inclination of the change in the attenuation to the change in the Faraday-rotation angle in the attenuator unit AU2 is contrary to this inclination in the attenuator unit AU1.
[0082] for example, when the Faraday-rotation angle in the attenuator unit AU2 is 90 degrees Since the power of a beam 124 all shifts to the power of a beam 134 theoretically and the power of a beam 126 all shifts to the power of a beam 138 theoretically The attenuation by the attenuator unit AU2 becomes the largest, and when the Faraday-rotation angle in the attenuator unit AU2 is 0 degree Since the power of a beam 124 all shifts to the power of a beam 132 theoretically and the power of a beam 126 all shifts to the power of a beam 136 theoretically, the attenuation by the attenuator unit AU2 becomes the smallest.
[0083] Therefore, when a control circuit 2 operates similarly in the 1st operation gestalt of drawing 1 , the wavelength property of the attenuation in the attenuator unit AU1 is substantially offset by the wavelength property of the attenuation in the attenuator unit AU2, and the wavelength property of the total attenuation in this optical attenuator becomes flat. Thus, according to this operation gestalt, the wavelength property of attenuation is flat and offer of an optical polarization attenuator for which it is not depended [for which attenuation does not depend on the polarization state of an input beam] is attained.
[0084] In the 4th operation gestalt of drawing 11 , using an optical fiber 58 and lenses 56 and 60, in order to connect optically between the attenuator units AU [AU1 and] 2 is based on the following reason. Namely, when the attenuator units AU1 and AU2 are optically connected by the space beam, without using an optical fiber 58 and lenses 56 and 60, As opposed to it being planned that a part or all of power of beams 112 and 116 shifts to the power of beams 132 and 136 in this optical attenuator It is because there is a possibility that the beam 114 which once swerved from the optical path, or the power of 118 may shift to the power of beams 132 and 136, and necessary attenuation may not be obtained. The main cause of this reunion [**** / un-] is in the place where the 2nd flat surface by which the 1st flat surface and the wedge board 48 by which the wedge board 44 and the rust angle which goes away 46 are defined, and the rust angle which goes away 50 are defined is mutually parallel. Therefore, by making it the relation which rotated one side of the 1st and 2nd flat surfaces focusing on the Z-axis to another side, when making it not mutually parallel [the 1st and 2nd flat surfaces], an optical fiber 58 and lenses 56 and 60 can be omitted, and the insertion loss of an optical attenuator can be stopped small. For example, the 1st and 2nd flat surfaces are mutually perpendicular. Specifically, it is as follows.
[0085] Drawing 12 is drawing showing the 5th operation gestalt of the optical attenuator by this invention. This operation gestalt is characterized in that the ellipsis of the optical fiber 58 and lenses 56 and 60 which are shown in drawing 11 by this is attained while 90 degrees of rust boards 44 and 46 which go away attenuator unit AU1 are rotated by the surroundings of the Z-axis as contrasted with the 4th operation gestalt of drawing 11 , respectively and it is arranged.
[0086] Therefore, the flat surface by which the wedge board 44 and the rust angle which goes away 46 are defined to the flat surface by which the wedge board 48 and the rust angle which goes away 50 are defined being parallel to YZ flat surface is parallel to XZ flat surface. Moreover, main shaft 44A is parallel to a Y-axis, and main shaft 46A is parallel to the X-axis.
[0087] Since he can understand the detail of the principle of operation of an optical attenuator including the attenuation in each of the attenuator units AU1 and AU2 being determined according to each Faraday-rotation angle according to the principle of operation in the 4th operation gestalt of drawing 11 , the explanation is omitted.
[0088] Also according to the 5th operation gestalt of drawing 12 , the wavelength property of attenuation is flat and

offer of an optical polarization attenuator for which it is not depended [for which attenuation does not depend on the polarization state of an input beam] is attained. Moreover, according to the 5th operation gestalt of drawing 12 , only in the part to which the optical fiber 58 and lenses 56 and 60 in the 4th operation gestalt of drawing 11 are abbreviated, the insertion loss of an optical attenuator becomes small.

[0089] Drawing 13 is drawing showing the measurement result of the wavelength property of the attenuation in the attenuator unit AU1 shown in drawing 12 . A vertical axis is the deflection (dB) of attenuation and a horizontal axis is wavelength (nm).

[0090] In the attenuator unit AU1, main shafts 44A and 46A are mutually perpendicular, and since the Faraday-rotation angle acquired according to increasing the drive current of the Faraday-rotation child's FR electromagnet 16 (refer to drawing 2) from 0 approaches 0 degree from 90 degrees, according to increasing drive current, attenuation should become large. It was set to 1.3dB, 2.0dB, 7.1dB, 13.4dB, 17.3dB, 21.8dB, and 27.1dB, as a result of setting drive current as 0mA, 5mA, 10mA, 15mA, 20mA, 25mA, and 30mA and measuring the attenuation to the wavelength of 1545nm, respectively. Moreover, according to increasing drive current, the inclination of the wavelength property of attenuation upward slanting to the right became large gradually. This measurement result is a match at the wavelength property of the attenuation explained by (A) of drawing 7 .

[0091] Although illustration was not carried out, in the attenuator unit AU2 shown in drawing 12 , it became clear that a wavelength property contrary to the wavelength property of drawing 13 is acquired. (A) - (D) of drawing 14 is a graph which shows the measurement result of the wavelength property of the total attenuation in the optical attenuator of the operation gestalt of drawing 12 . In each measurement, the light from Light Emitting Diode which serves as the white light source substantially in the given wavelength-range region (1530nm - 1560nm) was inputted into the optical attenuator, the output light of an optical attenuator was inputted into the optical spectrum analyzer, and the wavelength property of attenuation was measured.

[0092] (A) of drawing 14 is drive current I1 in the attenuator unit AU1. Drive current [in / the attenuator unit AU2 / it is set as 10.5mA and] I2 It is as a result of / when setting it as 7.9mA / measurement. The obtained attenuation was 10dB and the wavelength property of attenuation was fully flat.

[0093] (B) of drawing 14 is as a result of [when setting it as I1 =20.0mA and I2 =6.7mA] measurement. The obtained attenuation was 15dB and the wavelength property of attenuation was fully flat.

[0094] (C) of drawing 14 is as a result of [when setting it as I1 =25.8mA and I2 =6.2mA] measurement. The obtained attenuation was 25dB and the wavelength property of attenuation was fully flat.

[0095] (D) of drawing 14 is as a result of [when setting it as I1 =29.1mA and I2 =5.5mA] measurement. The obtained attenuation was 25dB and the wavelength property of attenuation was fully flat.

[0096] Drawing 15 is drawing showing the 6th operation gestalt of the optical attenuator by this invention. In the 5th operation gestalt of drawing 12 , in the Faraday-rotation child FR of the attenuator unit AU2, the adjustable magnetic field VM increases according to increasing drive current, and although the Faraday-rotation angle decreases so that 0 degree may be approached from 90 degrees, with the 6th operation gestalt of drawing 15 , Faraday-rotation child FR' with the reverse impression direction of the adjustable magnetic field VM and a fixed field system FM is used. Therefore, the Faraday-rotation angle increases toward 0 to 90 degrees by enlarging the drive current in Faraday-rotation child FR' from 0.

[0097] Moreover, with the 6th operation gestalt of drawing 15 , wedge board 50' which has main shaft 50A' which intersects perpendicularly with main shaft 48A of the wedge board 48 is used. Main shaft 50A' is parallel to the X-axis.

[0098] In this changed attenuator unit AU2, if a Faraday-rotation angle is 0 degree, attenuation of the attenuator unit AU2 becomes the largest and drive current is increased, when the drive current of Faraday-rotation child FR' is 0, since the Faraday-rotation angle approaches 90 degrees, attenuation of the attenuator unit AU2 becomes small.

[0099] Therefore, according to the 6th operation gestalt of drawing 15 , the wavelength property of attenuation is flat and offer of an optical polarization attenuator for which it is not depended [for which attenuation does not depend on the polarization state of an input beam] is attained so that I may be understood according to the principle of the 2nd operation gestalt of drawing 9 , and the 5th operation gestalt of drawing 12 .

[0100] Drawing 16 is drawing showing the 7th operation gestalt of the optical attenuator by this invention. Wedge board 50' which has main shaft 50A' parallel to the X-axis with the 7th operation gestalt of drawing 16 by the 5th operation gestalt of drawing 12 as contrasted with the wedge board 50 which has main shaft 50A parallel to a Y-axis being used is used.

[0101] Since it comes to have the inclination for the wavelength property of the attenuation in the attenuator units AU1 and AU2 to be the same according to this operation gestalt, offer of an optical polarization attenuator for which it is not depended [for which is the optical attenuator which can adjust the wavelength property of attenuation freely, and

attenuation does not depend on the polarization state of an input beam] is attained so that I may be understood according to the principle of operation in the 3rd operation gestalt of drawing 10 , and the 5th operation gestalt of drawing 12 .

[0102] Although offer of an optical polarization non-depended attenuator is enabled with the operation gestalt explained above with the combination of the wedge board which consists of a birefringence crystal, optical polarization non-depended attenuator can also be offered with a monotonous combination which consists of a birefringence crystal. In this case, when based on the combination of a wedge board, it is desirable to adopt a convergence beam system to having adopted the collimated beam system.

[0103] recent years -- low loss (for example, 0.2dB/(km)) -- the manufacturing technology and the used technology of an optical fiber are established, and the optical transmission system which makes an optical fiber a transmission line is put in practical use Moreover, in order to compensate the loss in an optical fiber and to enable long-distance transmission, use of the light amplifier for amplifying signal light is proposed, or it is put in practical use.

[0104] The light amplifier is equipped with the optical-amplification medium by which the signal light which should be amplified is supplied, and the means which carries out the pumping (excitation) of the optical-amplification medium so that the gain band where an optical-amplification medium contains the wavelength of signal light may be offered. For example, erbium dope fiber amplifier (EDFA) is equipped with the pump light source for supplying to EDF the pump light which has the wavelength beforehand determined as the erbium dope fiber (EDF) as an optical-amplification medium. By using the pump light which has the wavelength of 0.98-micrometer band or 1.48-micrometer band, the gain band containing wavelength the band of 1.55 micrometers is obtained. Moreover, the light amplifier using a semiconductor chip as an optical-amplification medium is also known. In this case, a pumping is performed by pouring current into a semiconductor chip.

[0105] On the other hand, there is a wavelength division multiplex (WDM) as technology for increasing the transmission capacity by the optical fiber. In the system by which WDM is applied, two or more optical carriers which have different wavelength are used. The wavelength division multiplex of two or more lightwave signals obtained by modulating each optical carrier independently is carried out by the optical multiplexer, and the WDM signal light obtained as a result is sent out to an optical-fiber-transmission way. In a receiving side, the received WDM signal light is divided into each lightwave signal by the optical demultiplexer, and transmission data are reproduced based on each lightwave signal. Therefore, according to the multiplex number concerned, the transmission capacity in one optical fiber can be increased by applying WDM.

[0106] A transmission distance is restricted by the wavelength property of the gain represented with a gain inclination (gain tilt) or gain deflection when including a light amplifier in the system by which WDM is applied. For example, in EDFA, a gain inclination arises in near with a wavelength of 1.55 micrometers, and it is known that this gain inclination will change according to the total input control power of the signal light to EDFA and the power of pump light.

[0107] Drawing 17 is the block diagram showing the operation gestalt of the system by this invention. This system is equipped with the optical-fiber-transmission way 68 where the wavelength division multiplex light (WDM light) containing two or more lightwave signals which have mutually different wavelength is transmitted, and the optical attenuator 70 by this invention prepared while being the optical-fiber-transmission way 68. The optical attenuator 70 has the attenuator units AU1 and AU2 for giving adjustable attenuation respectively to WDM light. The 1st wavelength property of attenuation of the attenuator unit AU1 differs from the 2nd wavelength property of attenuation of the attenuator unit AU2. Here, the wavelength of two or more lightwave signals contained in WDM light is lambda 1, --, lambdan, respectively.

[0108] When the optical-fiber-transmission way 68 contains two or more light amplifiers of an inline type, supposing each light amplifier has the wavelength property of gain in the band of WDM light, the wavelength property of the gain will accumulate and signal power or the deflection between channels of a signal-to-noise ratio (light SNR) will arise.

[0109] Since the wavelength property of the attenuation given by the optical attenuator 70 by constituting the optical attenuator 70 according to the 2nd side of this invention, for example can be adjusted freely, the wavelength property of the accumulated gain can be compensated with the operation gestalt of drawing 17 , and signal power and deflection between channels of Light SNR can be made small with it.

[0110] Or the wavelength property of the attenuation which may be produced in each of the optical attenuator units AU1 and AU2 by constituting the optical attenuator 70 according to the 1st side of this invention can be made to be able to offset substantially in the system currently controlled carefully so that the wavelength property of the gain in the optical-fiber-transmission way 68 may become a flat, and the wavelength property of the flat gain currently controlled can be maintained.

[0111] (A) of drawing 18 , (B), and (C) are the block diagrams showing the operation gestalt of the light amplifier by

this invention, respectively. Each light amplifier explains the composition and operation of each light amplifier as what is applied to the system of drawing 17 .

[0112] The light amplifier 71 is equipped with two optical-amplification units 72 (#1 and #2) and the optical attenuator 70 by this invention prepared among these with the operation gestalt shown in (A) of drawing 18 . The optical attenuator 70 is equipped with the attenuator units AU1 and AU2 for giving adjustable attenuation respectively, and the 1st wavelength property of attenuation of the attenuator unit AU1 differs from the 2nd wavelength property of attenuation of the attenuator unit AU2.

[0113] The WDM light which should be amplified is first amplified in the optical-amplification unit 72 (#1), and attenuation is given to the amplified WDM light by the optical attenuator 70. Subsequently the decreased WDM light is amplified in the optical-amplification unit 72 (#2), and is outputted from this light amplifier 71.

[0114] When the wavelength property of each gain of the optical-amplification unit 72 (#1 and #2) should be maintained, the 1st and 2nd wavelength properties are set up so that it may deny mutually. Or the 1st and 2nd wavelength properties may be set up so that the wavelength property (specifically wavelength property of the power of WDM light) of the light outputted from the optical-amplification unit 72 (#2) may become a flat.

[0115] The light amplifier 70 is connected to the output of the optical-amplification unit 72 with the operation gestalt shown in (B) of drawing 18 . In this case, the 1st and 2nd wavelength properties are set up so that it may deny mutually so that the wavelength property of the gain of the optical-amplification unit 72 may not change with operation of the optical attenuator 70.

[0116] The optical attenuator 70 is connected to the input of the optical-amplification unit 72 with the operation gestalt shown in (C) of drawing 18 . In this case, in order to make it the wavelength property of the WDM light which is supplied to the optical-amplification unit 72 and which should be amplified not change, the 1st and 2nd wavelength properties are set up so that it may deny mutually.

[0117] In addition, in (B) of drawing 18 , and the operation gestalt of (C), the 1st and 2nd wavelength properties may be set up so that the wavelength property of the gain which may be produced in a light amplifier 72 may be negated.

[0118] Drawing 19 is the block diagram showing the operation gestalt of the terminal equipment by this invention. Terminal equipment 74 is connected to the input edge of the optical-fiber-transmission way 68. Terminal equipment 74 is equipped with two or more E/O (electrical-and-electric-equipment/light) converters 76 (#1, --, #n) which output mutually different wavelength lambda 1, --, the lightwave signal that has lambdan, respectively, and the optical attenuator 70 (#1, --, #n) by this invention for adjusting the level of these lightwave signals. Each of the optical attenuator 70 (#1, --, #n) is used as the so-called level adjustment unit.

[0119] The wavelength division multiplex of the lightwave signal outputted from the optical attenuator 70 (#1, --, #n) is carried out by the optical multiplexer 78, and the WDM light obtained as a result is amplified by the light amplifier 71, and is supplied to the optical-fiber-transmission way 68. Each of the operation gestalt of (A) of drawing 18 , (B), and (C) is applicable to a light amplifier 71.

[0120] Each of the E/O converter 76 (#1, --, #n) contains the optical modulator 82 for modulating CW light outputted from the laser diode (LD) which outputs CW light (continuous wave light)80, and LD80 based on the main signal.

[0121] Since according to this operation gestalt the wavelength property of attenuation by application of this invention is a flat substantially in each of the optical attenuator 70 (#1, --, #n) or the desired wavelength property is acquired The wavelength property of the power of the lightwave signal outputted from each of the E/O converter 76 (#1, --, #n) can be maintained, and the wavelength property of the power in the WDM light obtained can be kept constant.

[0122] Moreover, since the light amplifier 71 has the optical attenuator 70 by this invention as the component, it can make flat the wavelength property of the power in the WDM light obtained, or can set it as a desired property.

[0123] In addition, the optical attenuator 70 (#1, --, #n) is omitted, terminal equipment 74 may be constituted, a light amplifier 71 may be omitted, and terminal equipment 74 may be constituted.

[0124]

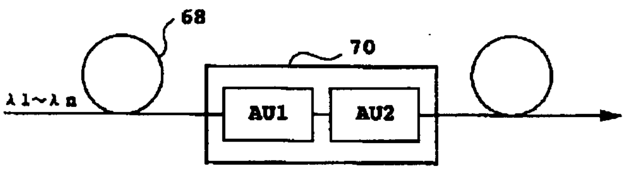
[Effect of the Invention] As explained above, according to this invention, the effect that offer of the optical attenuator which can adjust an optical attenuator with the flat wavelength property of attenuation or the wavelength property of attenuation is attained arises.

[0125] Moreover, according to the specific operation gestalt of this invention, offer of an optical polarization attenuator for which it is not depended [for which attenuation does not depend on the polarization state of an input beam] is attained. Furthermore, according to this invention, it is effective in offer of the new system equipped with the optical attenuator by this invention, a light amplifier, and terminal equipment being attained.

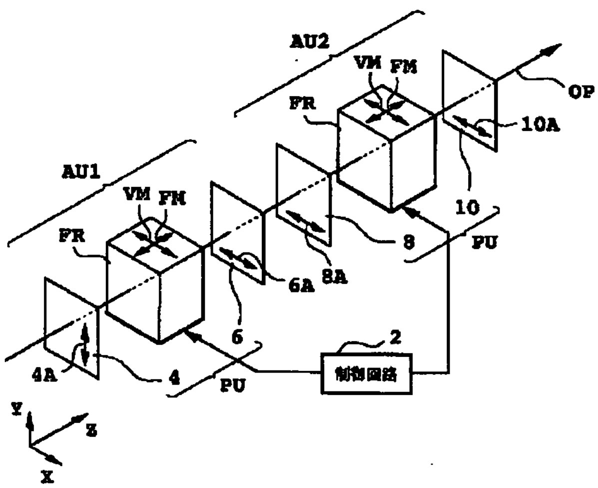
[Translation done.]

DRAWINGS

[Drawing 17]
本発明によるシステムの実施形態を示すブロック図

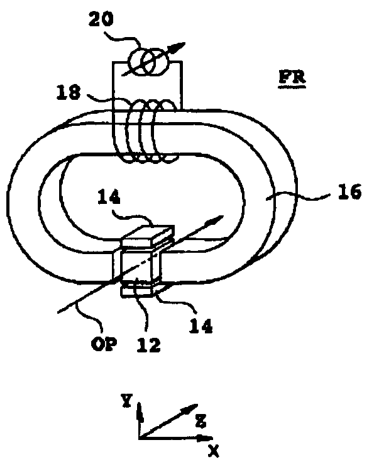


[Drawing 1]
光アッテネータの第1実施形態を示す図



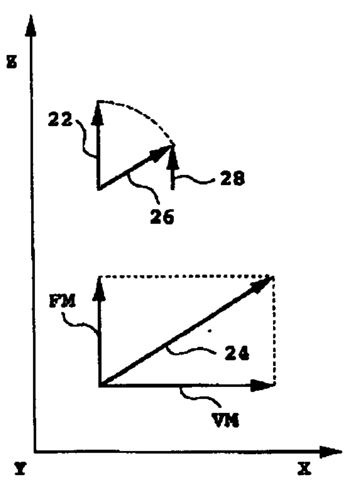
[Drawing 2]

ファラデー回転子FRの実施形態を示す図



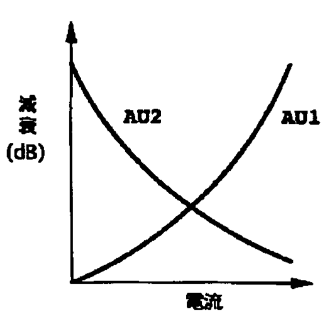
[Drawing 3]

図2のファラデー回転子FRで
ファラデー回転角が変化する原理を説明するための図



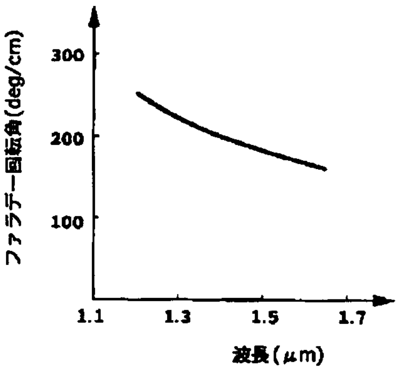
[Drawing 4]

図1のアッテネータユニットAU1及びAU2の
各々における減衰と駆動電流との関係を示すグラフ



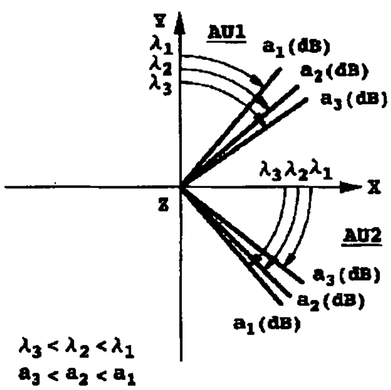
[Drawing 5]

ファラデー回転角の波長特性の一例を示すグラフ



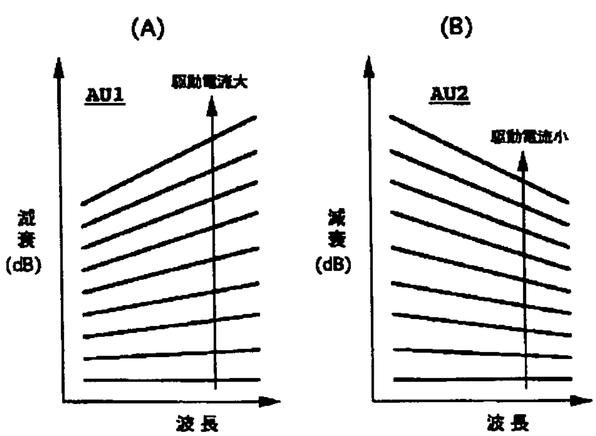
[Drawing 6]

図1の光アッテネータにおける各ファラデー回転角の
波長特性の影響を説明するための図



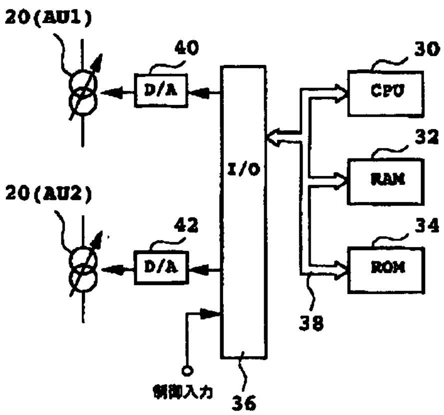
[Drawing 7]

図1のアッテネータユニットAU1及びAU2における
減衰の波長特性の変化を示す図



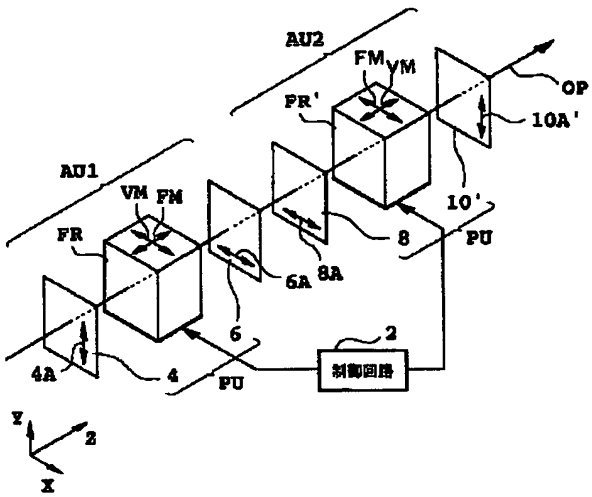
[Drawing 8]

制御回路2の実施形態を示すブロック図



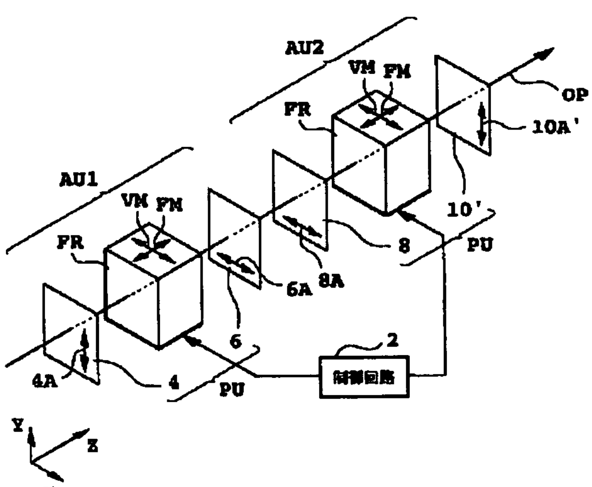
[Drawing 9]

光アッテネータの第2実施形態を示す図



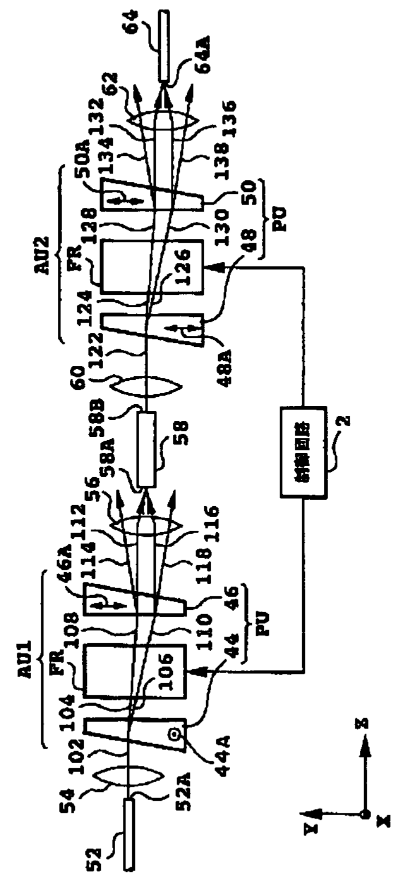
[Drawing 10]

光アッテネータの第3実施形態を示す図

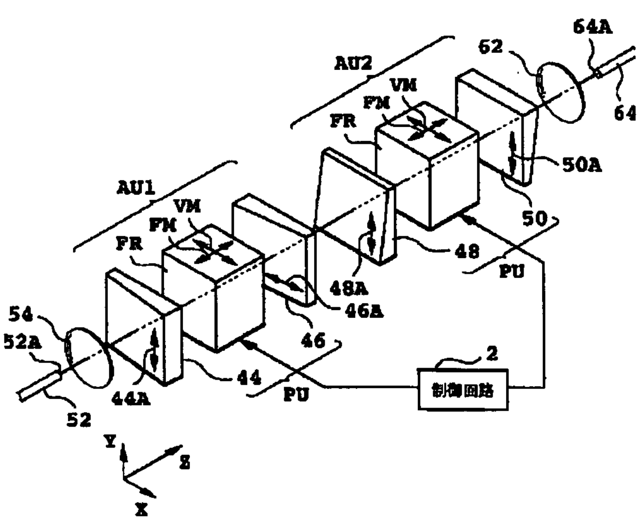


[Drawing 11]

光アッテネータの第4実施形態を示す図

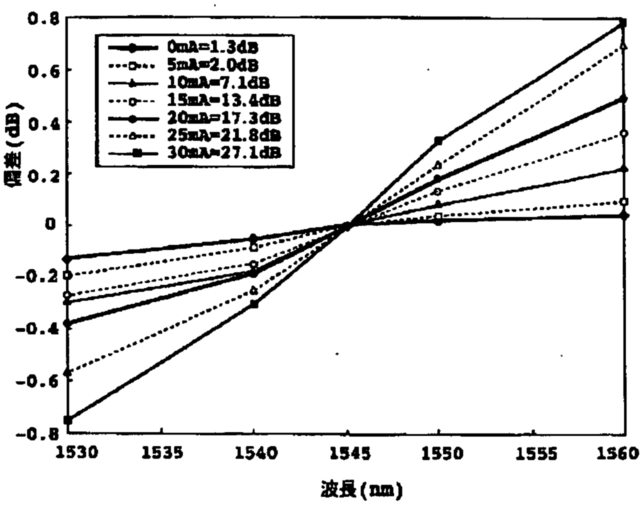


[Drawing 12]
光アッテネータの第5実施形態を示す図



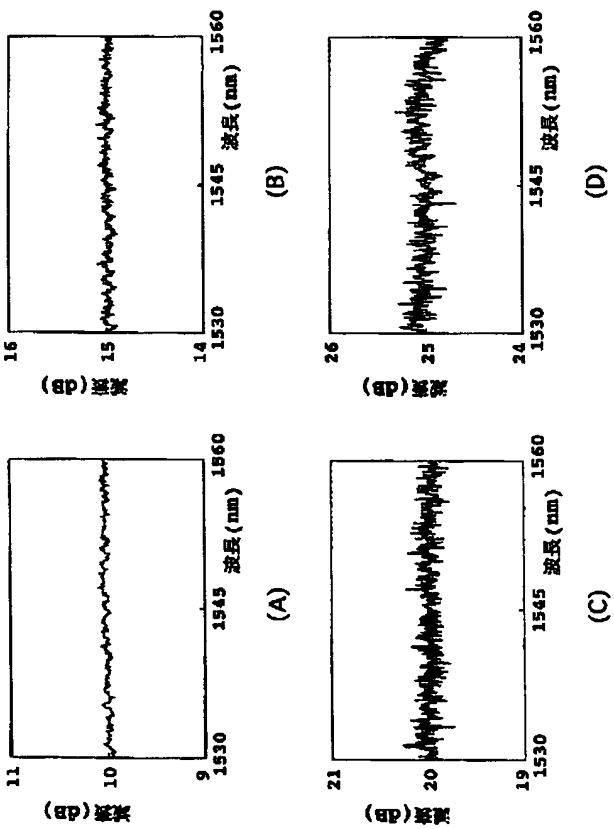
[Drawing 13]

図12のアッテネータユニットAU1における減衰の波長特性の
測定結果を示すグラフ



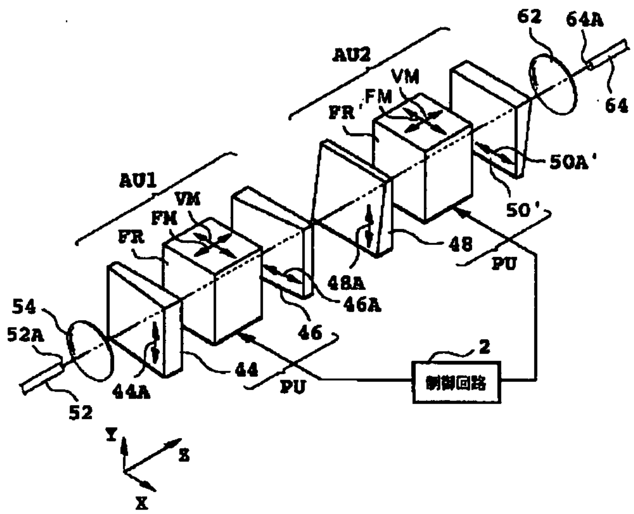
[Drawing 14]

図12の光アッテネータにおける
トータル減衰の波長特性の測定結果を示すグラフ



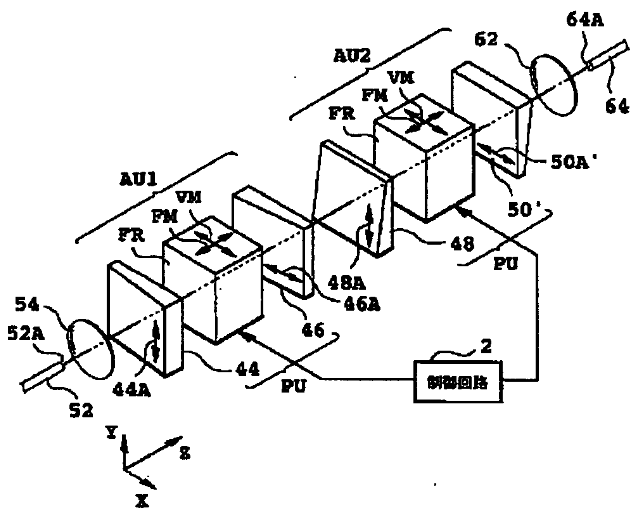
[Drawing 15]

光アッテネータの第6実施形態を示す図



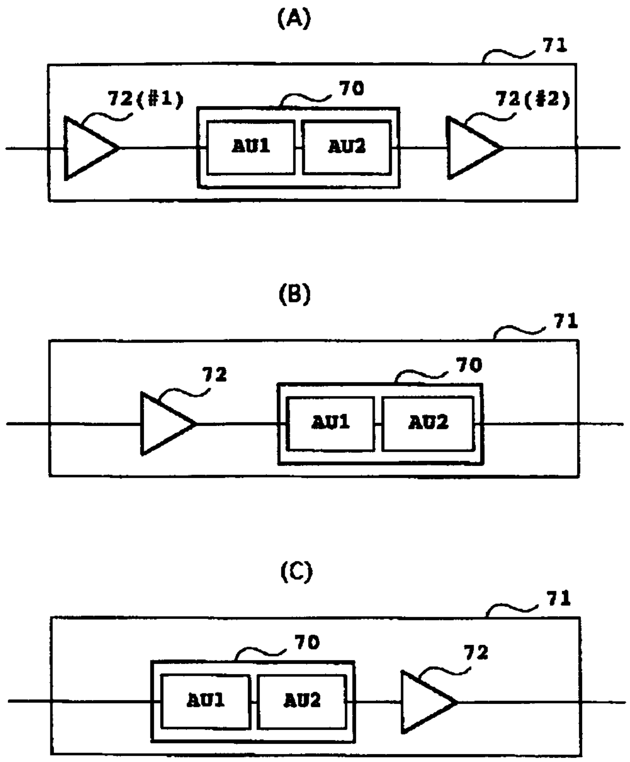
[Drawing 16]

光アッテネータの第7実施形態を示す図

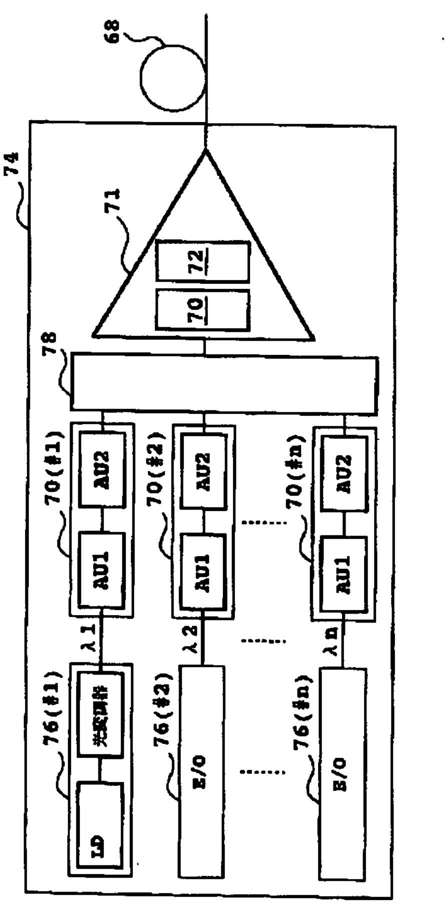


[Drawing 18]

本発明による光増幅器の実施形態を示すブロック図



[Drawing 19]
本発明による端局装置の実施形態を示すブロック図



[Translation done.]